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A STUDY OF COBALT 62

A Thesis

Presented in Partial Fulfillment of the Requirements  
for the Degree Master of Science

By

GORDON LYLE JACKS, B.Sc.

The Ohio State University

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## GENERAL INTRODUCTION

The study of artificial radioactivity has led to the development of many different experimental techniques. Conversely, an attempt to develop a new experimental technique, or a new piece of equipment, may well lead an investigator to study an unreported or questionable artificial radioactivity. Such a case has led to the report presented here. In an attempt to develop equipment and a technique for the study of short-lived radioisotopes, a 1.6 minute activity, resulting from the bombardment of nickel foil with deuterons, was observed. A search of the literature disclosed that the classification of this 1.6 minute activity was questionable. A study of this activity was undertaken, therefore, in an effort to verify previously reported experimental results and to properly identify the radiation and the isotope from which it arises.

## GENERAL INTRODUCTION

The study of artificial radioactivity has led to the development of many different experimental techniques. Generally, an attempt to develop a new experimental technique, or a new piece of equipment, may lead an investigator to study an unreported or questionable artificial radioactivity. Such a case was led to the report presented here. In an attempt to develop equipment and a technique for the study of short-lived radioisotopes, a 1.6 minute activity, resulting from the bombardment of nickel foil with deuterons, was observed. A search of the literature disclosed that the classification of this 1.6 minute activity was questionable. A study of this activity was undertaken, therefore, in an effort to verify previously reported experimental results and to properly identify the radiation and the isotope from which it arises.

## A STUDY OF COBALT 62

## A. A Description of Equipment

During the course of this investigation an "outside" probe was used for a majority of the bombardments performed at the Ohio State University cyclotron. The term "outside" is used as this particular probe allows the target sample to be bombarded at atmospheric pressure. Essentially, the sample is outside of the vacuum tank of the cyclotron when this probe is being used.

The probe was originally designed for use in bombarding tissue samples. When an attempt to study short-lived activities was made, it was thought that the outside probe could be modified in such a way as to allow the rapid extraction of the bombarded sample. This modification was easily accomplished, and the outside probe has proved extremely useful.

Described simply, the probe consists of a hollow tube, closed on one end. The closed end of the tube is inserted into the tank of the cyclotron. A very thin (0.0005 inches) copper foil, approximately  $3/8$ " by  $1/8$ " in dimensions, is used as a window in the closed end of the tube. The foil is strong enough to withstand the pressure from the inside of the tube when the probe is inserted into the vacuum system of the cyclotron. The bombarding particles pass from the vacuum tank of the cyclotron to the sample target through this window. Thus the target is bombarded outside of the cyclotron.

The target itself is fastened to a copper rod that will easily slide in and out of the hollow tube. With such an





arrangement, the target can be removed from the cyclotron beam and placed in a counter in approximately six seconds. Also, the length of bombardment time can be very closely regulated by using this outside probe.

All half-life measurements were made with a positron counter incorporating a Tracerlab "64" Scaler as the scaling circuit. A Geiger-Mueller tube was used as a counter. All absorption measurements were made with the same "64" Scaler and Geiger-Mueller tube, but the magnet of the positron counter was not utilized.

#### B. Experiments Performed and Results Obtained

The initial experiments were made by bombarding nickel foil with deuterons. The decay of the resultant activity was followed on the positron counter (without utilizing the magnet) and a 1.6 minute activity was found as shown in figure No. 1. The 3.4 hour activity observed was attributed to  $\text{Cu}^{61}$  and the 10 minute activity was attributed to  $\text{Cu}^{62}$ .

Further deuteron bombardments were carried out using nickel oxide as the target material. The beta (negatron) activity was followed on the positron counter and a 1.8 minute activity was observed (figure No. 2). The base line of this curve is the 12.9 hour  $\text{Cu}^{64}$  activity. Subtraction of this base line disclosed the 2.56 hour  $\text{Ni}^{65}$  activity. Further subtraction showed an 11 minute activity. This was attributed to  $\text{Co}^{60}$ . A final subtraction revealed the 1.8 minute activity.

Further deuteron bombardments were performed using

arrangement, the target was mounted from the direction beam  
and placed in a container in approximately the middle. Since  
the length of the container was not exactly regulated by  
using this method.

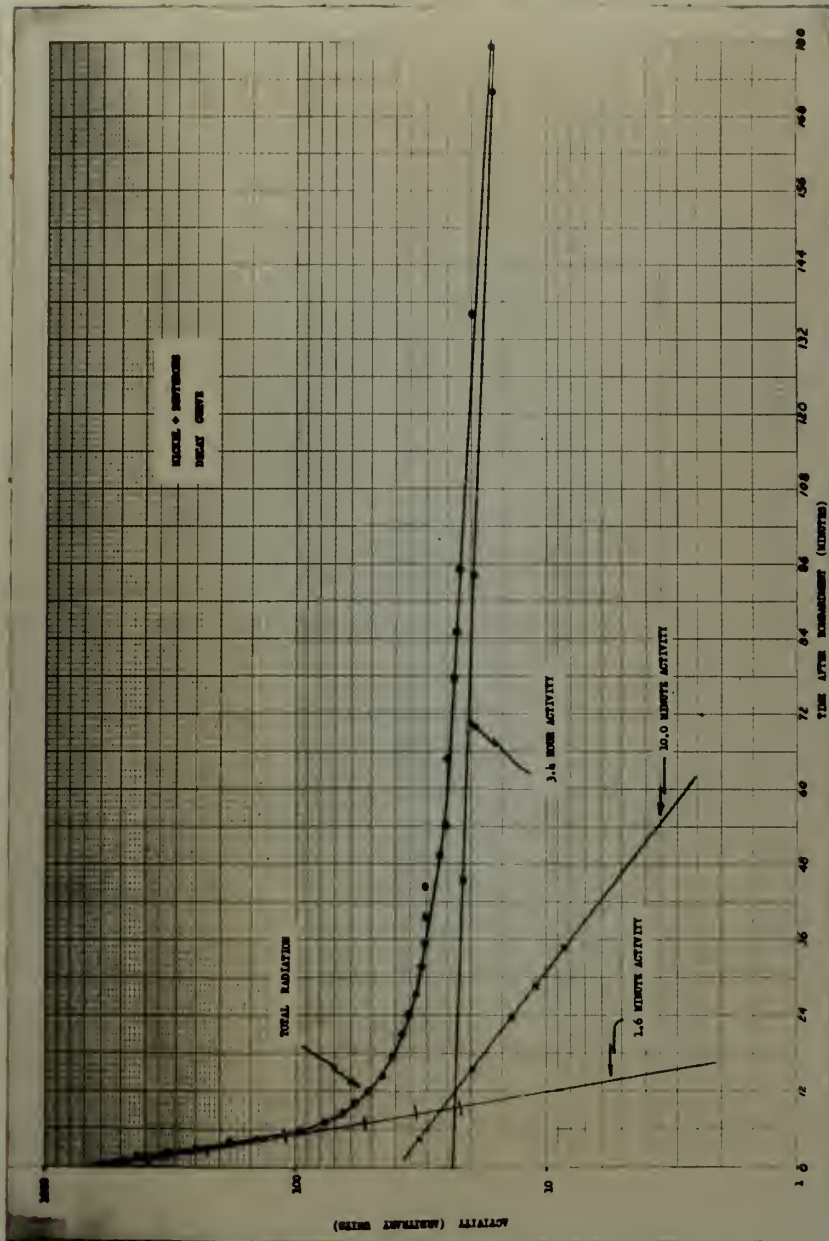
All half-life measurements were made with a Geiger-  
counter incorporating a Transistor Veto System as the scaling  
circuit. A Geiger-Müller tube was used as a scaler. All up-  
scaling measurements were made with the same Veto System and  
Geiger-Müller tube, but the output of the scaler was connected  
and utilized.

Half-life measurements were made with a Geiger-  
counter. The initial experiments were run by hand using a scaler  
followed by the scaler. The data of the resulting activity was  
followed on the scaler system (which utilized the scaler)  
and a 1.5 minute activity was found to occur in Figure 1.1.  
The 1.5 hour activity observed was attributed to  $^{60}\text{Co}$  and the  
10 minute activity was attributed to  $^{54}\text{Co}$ .

Further detailed measurements were carried out using  
linked tubes as the target material. The tube (measured) ac-  
tivity was followed on the scaler circuit and a 1.5 minute  
activity was observed (Figure 1.1). The two lines of activity  
were in the 1.5 hour  $^{60}\text{Co}$  activity. Measurement of this  
line was observed and the 1.5 hour  $^{60}\text{Co}$  activity. Further  
detailed measurements in 10 minute activity. This was attributed to  
a 1.5 hour activity revealed in 1.5 minute activity.

Further detailed measurements were carried out using







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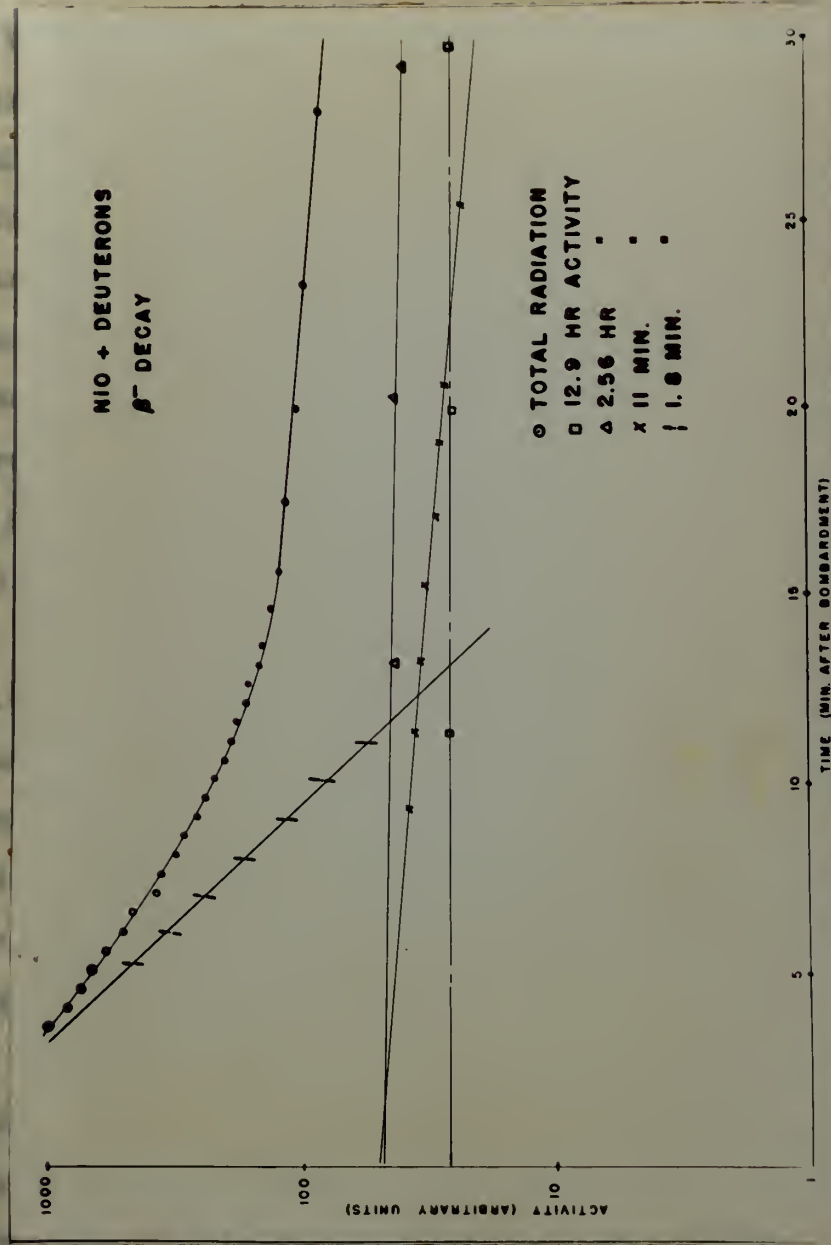


Figure No. 2



Figure No. 2



nickel oxide enriched in  $\text{Ni}^{64}$ . A study of the literature (1) had disclosed that the 1.6 minute activity arose from the deuteron bombardment of this particular nickel isotope. The percentage of  $\text{Ni}^{64}$  in the enriched sample was 80.6 percent. In naturally occurring nickel, this stable isotope of nickel has a percentage abundance of only 1.16 percent. The enriched sample was obtained from the Stable Isotopes Division, Oak Ridge National Laboratory. After bombardment with deuterons, the beta decay of the resultant activity was again followed on the positron counter. The 1.6 minute activity was disclosed by the graph after subtraction of the 2.6 hour  $\text{Ni}^{65}$  activity (figure No. 3).

An attempt to prove, from the branching ratios, that the 1.6 minute activity arose only from the deuteron bombardment of  $\text{Ni}^{64}$  was inconclusive. The  $\text{NiO}$  and  $\text{Ni}^{64}\text{O}$  were bombarded for only 30 seconds, yet the activity resulting was so great that it was necessary to wait for several minutes before attempting to use the positron counter. Thus, on the graphs, accurate extrapolation to "zero" time could not be made.

Other experiments were then conducted in an effort to classify the isotope giving rise to this 1.6 minute beta activity. Proton bombardments of nickel foil disclosed no 1.6 minute activity. Gamma ray bombardments of nickel foil resulted in no 1.6 minute activity. The gamma rays were obtained by bombarding lithium metal with protons. Neutrons, produced by hitting copper with deuterons, were used to bombard Ni foil and a definite 1.6 minute activity resulted, as shown in figure No. 4. Neutrons, produced by hitting gold with deuterons, were used to



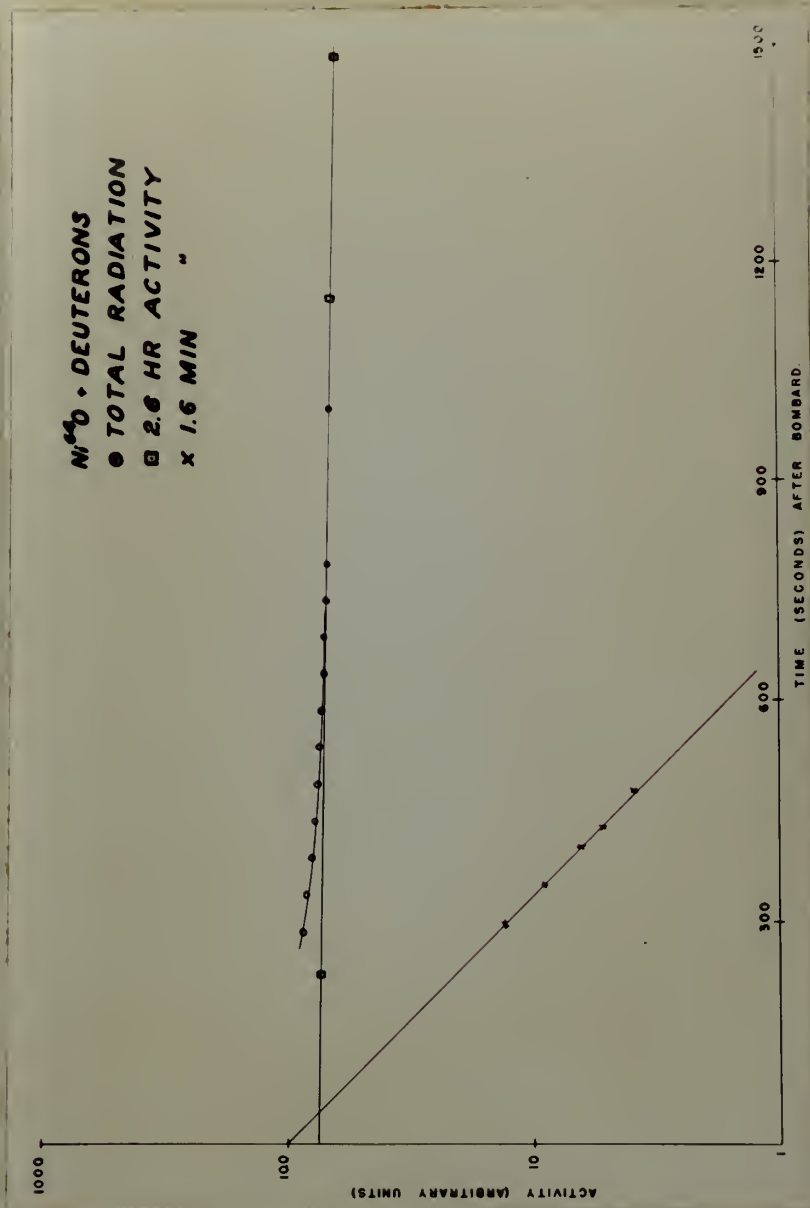


Figure No. 3



Figure No. 3



between the  $^{60}\text{Co}$  and  $^{60}\text{Fe}$  sources resulted (Figure No. 3). Several other experiments were conducted by substituting

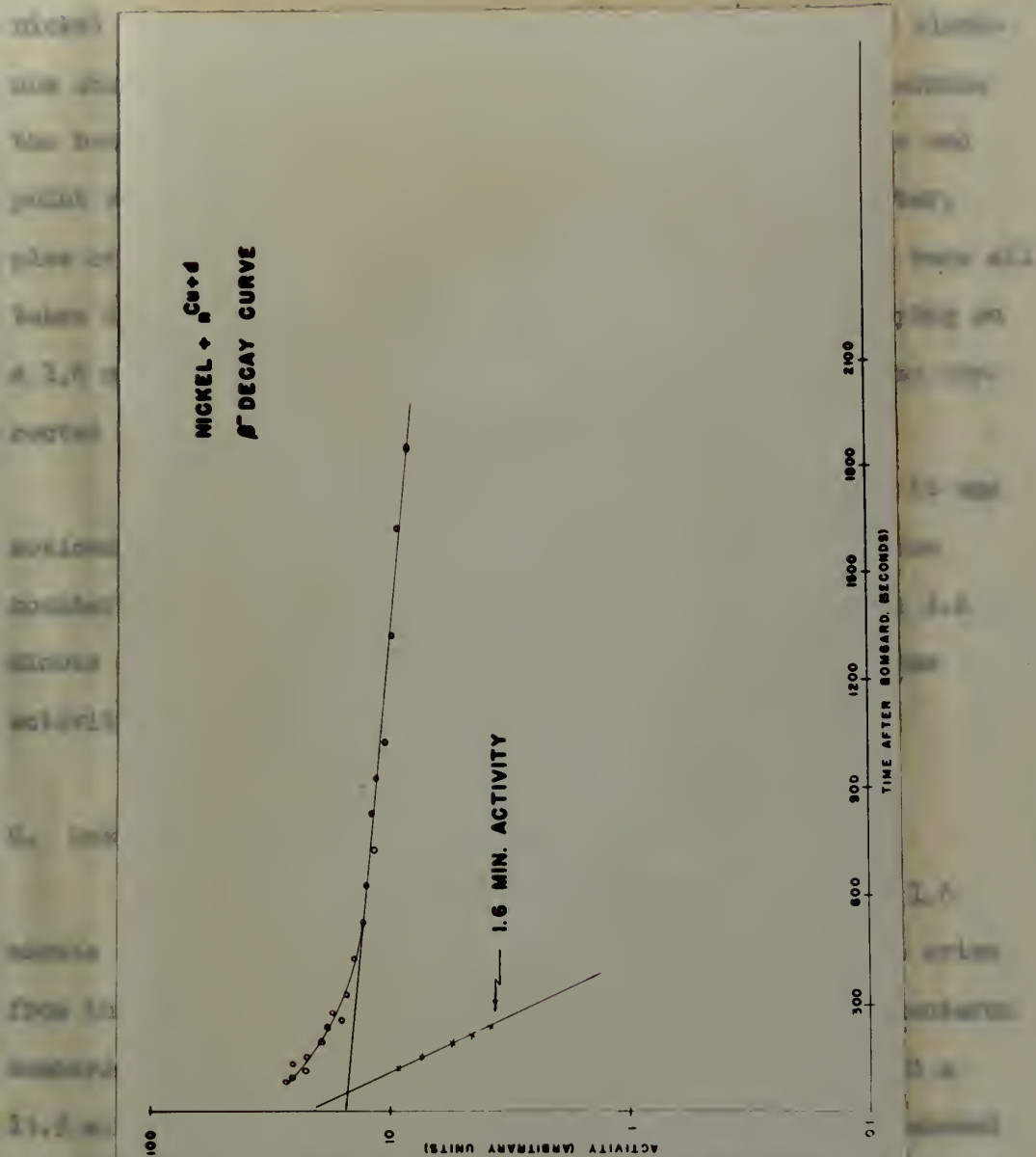


Figure No. 4

The fact that nothing was observed from the 1.7% source was not as apparent in the data as it is significant.



Figure No. 1

bombard the  $\text{Ni}^{64}$ . No 1.6 minute activity resulted (figure No. 5).

Several other experiments were conducted by bombarding nickel foil with deuterons for a period of five seconds. Aluminum absorption measurements were made in an effort to determine the beta end point energy of the 1.6 minute activity. The end point was determined as 1550 milligrams of aluminum absorber, plus or minus 50 milligrams. The absorption measurements were all taken during a time interval in which the sample was decaying on a 1.6 minute half life, and each absorption measurement was corrected for the decay of the sample (figure No. 6).

During the course of several of the experiments it was noticed, from sample background measurements on the positron counter, that a short-lived gamma activity accompanied the 1.6 minute beta activity. Half life determinations of the gamma activity showed a period of approximately 1.9 minutes.

### C. Results Reported Previously

A study of the literature (1) revealed that the 1.6 minute activity, both beta and gamma, had been observed to arise from the fast neutron bombardment of  $\text{Ni}^{62}$  as well as the deuteron bombardment of  $\text{Ni}^{64}$ . The neutron bombardment also revealed a 13.9 minute beta and gamma activity. Chemical separation showed the 13.9 minute activity to be in the cobalt fraction. The investigators assigned the 13.9 minute activity to cobalt 62. The basis for the assignment is as follows:

"The fact that nothing shorter than the 1.75 hour cobalt 61 appeared in the cobalt from nickel 61 is significant

position the  $^{60}\text{Co}$ . The 1.5 minute activity revealed (figure No. 2).

Several other experiments were conducted by bombarding nickel foil detectors for a period of five weeks. Almost one absorption measurement was made in an effort to determine the beta end point energy of the 1.5 minute activity. The end point was determined as 1550 milligrams of aluminum absorber, plus or minus 50 milligrams. The absorption measurements were all taken during a time interval in which the sample was decaying at a 1.5 minute half life, and each absorption measurement was corrected for the decay of the sample (figure No. 3).

During the course of several of the experiments it was noticed, from sample background measurements on the position counter, that a short-lived gamma activity accompanied the 1.5 minute beta activity. Half life determinations of the gamma activity showed a period of approximately 1.5 minutes.

### C. Results Reported Previously

A study of the literature (1) revealed that the 1.5 minute activity, both beta and gamma, had been observed to arise from the fast neutron bombardment of  $\text{Ni}^{60}$  as well as the neutron bombardment of  $\text{Ni}^{60}$ . The neutron bombardment also revealed a 13.9 minute beta and gamma activity. Gamma-ray experiments showed the 13.9 minute activity to be in the cobalt position for investigations assigned the 13.9 minute activity to cobalt 57. The beta for the assignment is as follows:

"The first clear beta-ray spectrum from the 1.75 hour half life reported in the cobalt line which is significant



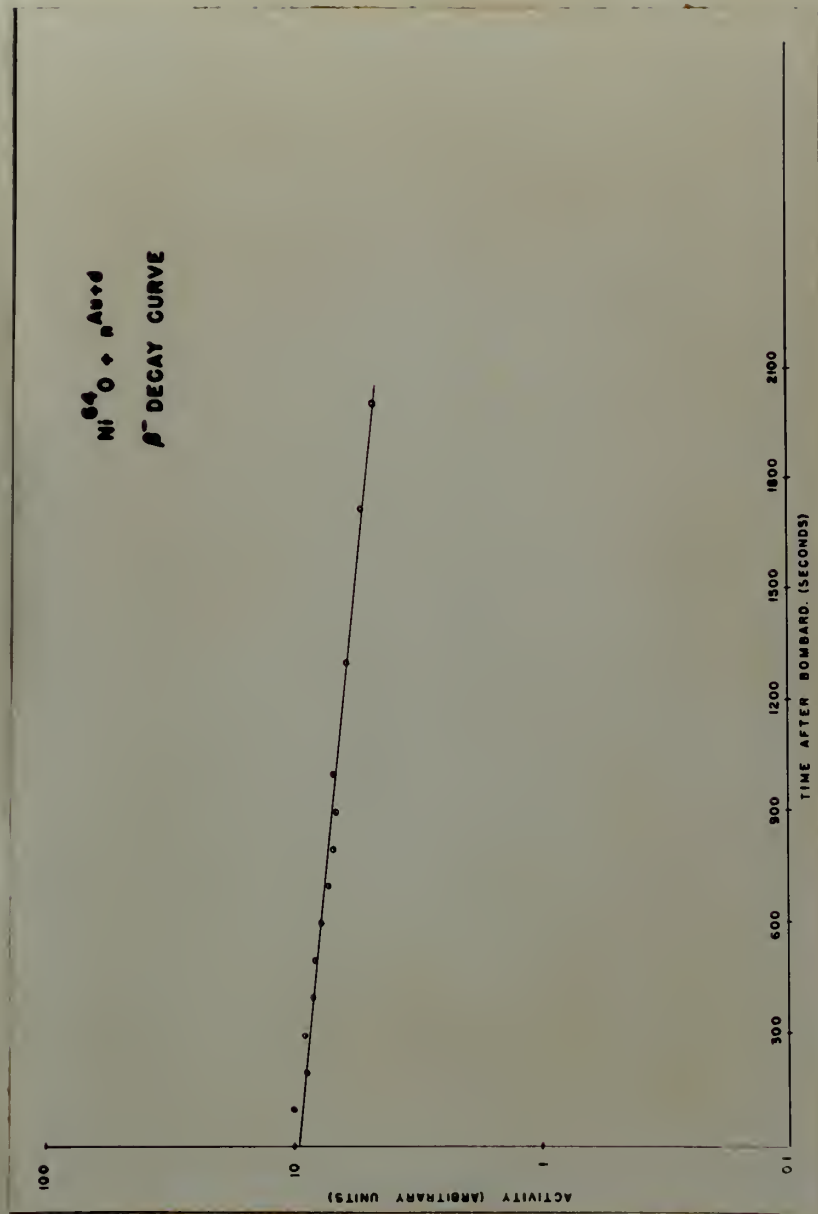


Figure No. 5



Figure No. 2

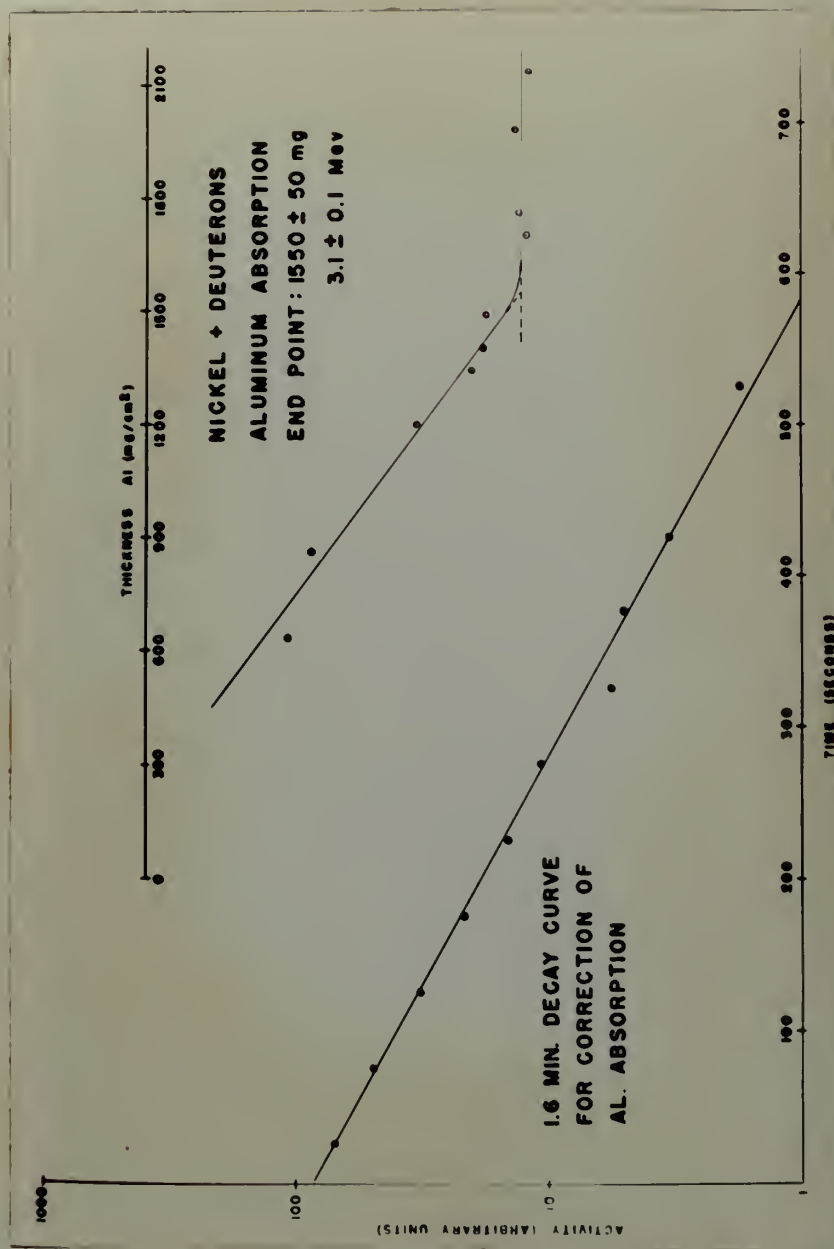


Figure No. 6



Plate No. 10



since an (n,pn) reaction should yield  $\text{Co}^{60}$  which has a 10.7 minute activity. Inasmuch as this activity does not appear in the  $\text{Ni}^{61}$  sample it implies that the yield of (n,pn) reactions here is probably negligible. These facts make it apparent that the 13.9 minute decay is associated with an (n,p) reaction in  $\text{Ni}^{62}$  yielding  $\text{Co}^{62}$ ." The quotation has been taken from the published report.

The 1.75 hour activity mentioned above resulted from the neutron bombardment of  $\text{Ni}^{61}$  and has been definitely established as arising from  $\text{Co}^{61}$ . Both chemical and mass separations were performed in order to positively assign this activity.

The investigators tentatively assigned the 1.6 minute activity to  $\text{Co}^{62}$ . It was thought to be isomeric with the 13.9 minute activity since it also arose from the fast neutron bombardment of  $\text{Ni}^{62}$ . The 1.6 minute activity was thought to result from a (d, $\alpha$ ) reaction when the  $\text{Ni}^{64}$  was bombarded with deuterons.

#### D. Conclusions

On the basis of the experimental results obtained at the Ohio State University cyclotron, it is felt that the following conclusions can be made:

1. The 1.6 minute activity probably arises from  $\text{Co}^{62}$  produced by a (d, $\alpha$ ) reaction in  $\text{Ni}^{64}$ . The activity appeared from all deuteron bombardments of nickel foil, nickel oxide, and enriched nickel 64. The 1.6 minute activity also resulted from the neutron bombardment of nickel foil, probably due to a (n,p) reaction on the nickel 62 present in the nickel foil. The fact that the activity did not arise from the proton bombardment of

since an (n,p) reaction would yield  $^{60}\text{Co}$  which has a 5.27 minute activity. Inasmuch as this activity does not appear in the  $^{60}\text{Co}$  sample it follows that the (n,p) reaction does not appear to be a significant reaction. These facts were in agreement with the 1.2 minute activity associated with the (n,p) reaction in  $^{60}\text{Co}$ . The reaction has been taken from the previous report. The 1.2 hour activity mentioned above results from the neutron bombardment of  $^{61}\text{Ni}$  and has been definitely identified as arising from  $^{61}\text{Ni}$ . Both channels and were investigated were found to be positively as a result of this activity. The investigators tentatively assigned the 1.2 minute activity to  $^{60}\text{Co}$ . It was thought to be identical with the 1.2 minute activity since it also arose from the fast neutron bombardment of  $^{61}\text{Ni}$ . The 1.6 minute activity was thought to arise from a (n,p) reaction when the  $^{61}\text{Ni}$  was bombarded with neutrons.

## D. Conclusions

On the basis of the experimental results obtained in the fast neutron bombardment of  $^{60}\text{Co}$ , it is felt that the following conclusions can be made:

1. The 1.2 minute activity previously assigned to  $^{60}\text{Co}$  produced by a (n,p) reaction in  $^{60}\text{Co}$ . The activity assigned to  $^{60}\text{Co}$  from all neutron bombardments of nickel foil, nickel wire, and enriched nickel foil. The 1.6 minute activity also resulted from the neutron bombardment of nickel foil, probably due to a (n,p) reaction on the nickel (p) present in the nickel foil. The fact that the activity did not arise from the proton bombardment of

nickel tends to preclude the assignment of the activity to a copper isotope. The results of the gamma bombardment of nickel foil, and the neutron bombardment of  $\text{Ni}^{64}\text{O}$  tend to preclude the assignment of the activity to a nickel isotope.

2.  $\text{Co}^{62}$  decays by emitting a 3.1 Mev beta particle and a gamma ray of undetermined energy. The half life of this radioactive isotope is 1.6 minutes.

3. The 13.9 minute beta and gamma activity previously reported (1) is not isomeric with the 1.6 minute  $\text{Co}^{62}$  activity. It is possible that this 13.9 minute activity belongs to some other cobalt isotope. This conclusion is based on energy considerations. The reported energy (1) of the beta particle associated with this 13.9 minute activity is 2.3 Mev. The observed energy of the beta particle associated with the 1.6 minute activity is 3.1 Mev. Thus, any deuteron beam capable of producing the 1.6 minute activity must also produce the 13.9 minute activity if the two activities are isomeric. Since the 13.9 minute activity was never observed to arise from any of the deuteron bombardments performed by this investigator, it is felt that the 13.9 minute activity is not isomeric with the 1.6 minute activity and should not, therefore, be assigned to  $\text{Co}^{62}$ .

Further work is apparently necessary to clarify the assignment of the 13.9 minute activity. The experimental results obtained by this investigator are not in agreement with the results obtained by others. For the present, it is suggested that the classification of this 13.9 minute activity be considered doubtful until further experimental data is collected.



which tends to produce the assignment of the activity to a single  
 category. The results of the same experiment of which fall,  
 and the further experiment at 10<sup>10</sup> level to produce the  
 assignment of the activity to a single category.  
 2. (a) Activity by emitting a 3.1 sec data particle and a  
 same set of undetermined energy. The half life of this activi-  
 tive category is 1.0 minutes.  
 3. The 1.9 minute data and gamma activity category  
 reported (1) is not identical with the 1.0 minute  $^{60}\text{Co}$  activity.  
 It is possible that this 1.9 minute activity belongs to some  
 other source category. This conclusion is based on energy con-  
 siderations. The reported energy (1) of the beta particle asso-  
 ciated with this 1.9 minute activity is 1.3 Mev. The observed  
 energy of the beta particle associated with the 1.0 minute ac-  
 tivity is 3.1 Mev. Thus, any distinction from category of producing  
 the 1.0 minute activity must also produce the 1.9 minute ac-  
 tivity if the two activities are identical. Since the 1.9  
 minute activity was never observed to arise from any of the dis-  
 tinct radioactive particles in this investigation, it is fair  
 to say the 1.9 minute activity is not identical with the 1.0 min-  
 ute activity and should not, therefore, be assigned to  $^{60}\text{Co}$ .  
 Therefore with the experiment necessary to identify the  
 assignment of the 1.9 minute activity. The experimental re-  
 sults obtained by this investigation are not in agreement with  
 the results obtained by others. For the present, it is suggested  
 that the identification of this 1.9 minute activity be con-  
 sidered doubtful until further experimental data is collected.

## BIBLIOGRAPHY

- (1) T. J. Parmley, B. J. Moyer, R. C. Lilly, Physical Review 75,  
619, 15 Feb. 1949.

1995-1996

- (12) *Y. A. Izrael, Zh. tekhn. fiz.*, **32**, 10 (1966), English transl. in *Technical Physics* **11**, 10 (1966).

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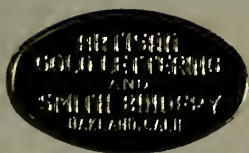
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